ADAPTIVE DISCRETE SLIDING MODE CONTROL OF AN ELECTRO-HYDRAULIC ACTUATOR SYSTEM

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To my lovely wife and son ...
Farhaana Yakop and Khalish Rozaimi

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ABSTRACT

This thesis presents system identification and development of an adaptive robust control strategy based on discrete sliding mode control (DSMC) with zero phase error tracking control (ZPETC) for an electro-hydraulic actuator (EHA) system. A linear type actuation of the EHA system using a single-ended cylinder controlled by a servo valve was considered in the experimental design. In the system identification process, EHA system was modelled using parametric linear time varying equations with parameters that were identified using recursive and non-recursive identification techniques. An identification process that recursively computes the dynamic model was performed using recursive least square with varying forgetting factors and the estimated linear model was validated through statistical approaches. From the identification process, a non-minimum phase model of EHA system with a high sampling time was obtained. To formulate the control algorithm for the EHA system, a robust feedback control theory with feedforward structure was employed to overcome the non-minimum phase problem in EHA system. The algorithm was also subjected to model uncertainty and non-linear characteristics. As a result, a new robust controller with an integrated design scheme based on DSMC and ZPETC was developed using a reaching law technique where parameters of the controller had been analytically determined. Subsequently, the new adaptive control strategy was improved by enhancing DSMC and ZPETC that are adaptable with variations in the parameters of EHA system. In simulation and experimental studies, an optimal linear-quadratic-regulator (LQR) and a proportional-integral-derivative (PID) were implemented in the position tracking control as comparisons with the proposed robust controller. A comprehensive performance evaluation with quantitative measures of the tracking performance is presented and the results show that the robust system performance was achieved with DSMC under different operating system conditions. The findings also demonstrated that the new adaptive DSMC with ZPETC structure has reduced the control effort and gave a better performance in terms of tracking accuracy as compared to the conventional DSMC, LQR and PID controllers.

ABSTRAK

Tesis ini mengemukakan pengenalpastian sistem dan pembangunan sebuah teknik kawalan tegap mudah suai berdasarkan kawalan ragam lincir diskret (DSMC) dengan teknik kawalan ralat penjejak fasa sifar (ZPETC) untuk sistem penggerak elektro-hidraulik (EHA). Sebuah penggerak jenis linear bagi sistem EHA menggunakan silinder berhujung tunggal yang dikawal oleh injap servo telah dipertimbangkan di dalam rekabentuk ujikaji. Di dalam proses pengenalpastian sistem, sistem EHA dimodelkan menggunakan persamaan linear berparameter masa berubah dengan parameter tersebut telah dikenalpasti menggunakan teknik pengenalpastian rekursif dan tidak rekursif. Sebuah proses pengenalpastian yang mengira secara rekursif model dinamik telah dijalankan menggunakan kuasa dua terkecil rekursif dengan faktor pemadaman berubah dan anggaran model linear tersebut telah disahkan melalui pendekatan statistik. Daripada proses pengenalpastian, sebuah model fasa tidak minima sistem EHA telah diperolehi dengan persampelan masa tinggi. Bagi perumusan algoritma kawalan untuk sistem EHA, teori kawalan suap balik tegap dengan struktur suap depan telah digunakan untuk mengatasi masalah fasa tidak minima di dalam sistem EHA. Algoritma tersebut juga mengalami ketidakpastian model dan ciri tidak linear. Hasilnya, sebuah pengawal tegap baru dengan skim rekabentuk berintegrasi berdasarkan DSMC dan ZPETC telah dibangunkan menggunakan teknik hukum mencapai di mana parameter pengawal telah ditentukan secara beranalitik. Kemudiannya, sebuah strategi kawalan mudah suai baru ditambah baik dengan peningkatan DSMC dan ZPETC yang boleh suai terhadap perubahan parameter di dalam sistem EHA. Di dalam kajian penyelakuan dan ujikaji, sebuah pengatur-kuadratik-linear (LQR) optima dan kadaran-kamiran-terbitan (PID) telah dilaksanakan di dalam kawalan penjejak kedudukan sebagai perbandingan dengan pengawal tegap yang dicadangkan. Penilaian prestasi komprehensif dengan sukatan kuantitatif bagi prestasi penjejak dikemukakan dan keputusan menunjukkan bahawa prestasi sistem tegap telah dicapai dengan DSMC bagi keadaan sistem yang berbeza. Penemuan ini juga menunjukkan bahawa DSMC mudah suai baru dengan struktur ZPETC telah mengurangkan usaha pengawal serta memberi prestasi yang lebih baik dalam terma ketepatan penjejakan berbanding pengawal konvensional DSMC, LQR dan PID.